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THE AMERICAN
METEOROLOGICAL JOURNAL.

VOL. VI. ANN ARBOR, OCTOBER, 1889. No. 6.

ORIGINAL ARTICLES.

THE DETERMINATION OF THE AMOUNT OF RAINFALL.

BY PROFESSOR CLEVELAND ABBE.

The accurate measure of rain is a matter of equal importance to meteorology and engineering, but like all other problems in physics the accurate determination of any datum must be accompanied by a determination of the reliability of, or the confidence to be placed in, the numerical results. There must be some estimate or determination of the "possible error" or the "probable error" of the result of our measures, before we can safely make use of that result for any further deductions.

Many investigations have been made into the reliability of rainfall measures, by means of comparative observations with gauges of various patterns placed in diverse localities with regard to surrounding obstacles, and at different heights in respect to the surface of the ground, or at different altitudes with respect to the surface of the sea.

The general result of these investigations, so far as rain proper is concerned, is about as follows:

(1) So far as concerns the size and shape of the collecting funnel; circular and square apertures of from ten to one hundred square inches area give results that vary only one or two per cent. among themselves.

(2) *As Regards the External Shape of the Gauge as a whole:*

Simple cylinders or cylinders with small rims or bulging rings, or conical flanges vary but two or three per cent. among themselves on account of shape, but all catch decidedly less than cylinders with broad flanges or shields near their apertures as in the Henry and the Nipher gauge. The excess of the catch in these shielded gauges increases slightly in proportion to the force of the wind.

(3) *As Regards the Location:* Gauges on the ground close to the windward side of an obstacle catch more than those in the open field; gauges close to the leeward side catch less, while gauges a little farther to the leeward catch decidedly more; gauges on the top of the obstacle, such as the flat roof of a house, catch less when they are near the windward side, but the same or a little more than the normal when they are nearer the leeward side of the roof. This shows that the presence of an obstacle in conjunction with the wind alters the distribution of what would otherwise be a uniform rainfall; the alteration increases more rapidly than the increase of the wind, and is approximately as the square of the velocity.

(4) *With Regard to Elevation Above Sea Level:* Whether on an isolated mountain or on a broad rising plateau, on the windward side the rainfall increases up to a certain elevation and then diminishes rapidly, but on the leeward side there is only a rapid diminution from the summit downwards. In some cases this latter diminution causes an entire absence of rain over the greater part of the leeward side of the plateau or mountain; in many cases the available mountains are scarcely high enough to enable us to observe the diminution of rain above the belt of maximum precipitation.

(5) *With Regard to the Altitude Above Ground:* The higher gauges invariably catch less rain, and the discrepancies caused by altitude are so large as to have hitherto been considered as the principal source of uncertainty in rainfall measurements, so that for gauges of uniform patterns exposed in unobjectionable locations in open fields, the only method hitherto prescribed for securing comparable results has consisted in the adoption of a uniform small elevation above ground: but this rule of course

gives us no assurance that our rainfall measurements are correct in any absolute sense. The general explanation of the fact that the higher gauges catch less rain, as given by Bache and Jevons, was that the wind causes eddies about the mouth of the gauge and carries past some of the raindrops. This explanation is undoubtedly true and suffices to explain many observed phenomena: but if true, it should be followed out to its logical consequences and be made to give us some method of correcting the record of a gauge for the influence of the wind so as to obtain a nearer approximation to the rain that has actually fallen upon the ground; this I will now attempt to do:

(6) In the case of ordinary rainfalls the air is full of large and small drops intermixed, or of heavy and light flakes of snow; near the ground are additional fragments of drops broken up by spattering, and again during snow storms with high winds, the air is full of flakes that have been whirled up into the air after having once fallen to their resting place on the ground or trees. I shall for the present omit the consideration of spattering and drifting, hoping to treat of them at some future time, and will consider only the effect of the wind on the drops falling directly into a gauge whose mouth is high enough above the ground to avoid these two influences; in fact, spattering and drifting can only influence the local distribution of rain or snow, a gauge placed within their influence must have its readings thereby increased, and the true amount of precipitation is more easily obtained by the method I shall present, if the gauges are raised a few feet above the ground.

We therefore consider that there is falling into the gauge a quantity of drops or flakes of various sizes and various vertical velocities while the wind is blowing horizontally against the gauge.

(7) Now when the wind strikes the gauge the deflected current just above the mouth of the gauge acquires a vertical component that it did not have before it struck the gauge, and also has a horizontal motion more rapid than it had before, more rapid than that of the wind a few inches higher up. The larger drops of the falling rain may descend with a rapidity

sufficient to penetrate this swiftly moving layer and enter the gauge, but the smaller drops falling more slowly will be carried over to the leeward of the gauge and failing to enter it, will miss of being measured as rainfall, although they really go on and fall to the ground near by. Evidently, of two masses of rain having the same proportion of large and small drops, or rapid and slow falling snow flakes, the proportion of small drops that are carried by, will be large in proportion as the wind is stronger, the deficiency in the catch of the gauge being very nearly proportional to the velocity of the wind. Again, for the same gauges and the same velocity of wind, the deficiency will be proportional to the relative percentage of small and slow falling drops that occur in any given shower. Thus we easily see that the deficiency will be greater in winter snows than in summer rains; greater in fine drizzling rains than in heavy downfalls; greater in windy localities; greater for elevated gauges than for low ones. The application of these ideas gives us a satisfactory general explanation of the numerous irregularities that have been observed in rainfalls. In fact they explain every one of the most extreme cases, such, *i. e.*, as that recorded by the Signal Service observer at Kitty Hawk, on the sandy beach of North Carolina, where nine experimental gauges were by request established in a cluster fully exposed to the wind, with their mouths two or three feet above the surface of the sand; the windward gauges of the cluster caught less rain that the leeward, but they also caught very much more sand, showing that the strong winds which carried the light raindrops on beyond to the leeward gauges, also stirred up the light surface sand and were just able to drop this into the windward gauges.

(8) The numerical results of all rainfall observations at different elevations of the gauge, have been collected by me in a memoir read before the Philosophical Society of Washington, in December, 1888; most of these are also given in the excellent memoir of Wild, in Volume IX of his Repertorium, 1885. These observations represent many years of rainfall in a great variety of climates in the United States and Western Europe, and continued as they were through summer and winter, they represent

the average effects (due to the proportion between the precipitations that descend rapidly and slowly with the accompanying winds) characteristic of the respective climates. The following table shows the numerical results. In the fourth column are given the catch of the respective gauges expressed in percentage of the catch of the normal pit-gauge; the fifth column gives the deficit by groups of this percentage; the sixth column gives the square root of the altitude:

TABLE.

LOCATION.	No. of Years.	Altitude Meters	Relative Catch.	Relative Deficit	Square Root of Altitude	$\sqrt{}$ Alt.
.....		0	100	0	0	0
Calne; 5 and 8 inch gauges.....	4	1	90	10	1.00	6
Castleton; 5 and 8 inch gauges ...	3	2	88	12	1 41	8
Rotherham; 5 inch gauges.....	8	3	86	14	1.73	10
St. Petersburg; 10 inch gauges....	10	4	85	15	2.00	12
....		5	85	15	2.24	13
....		6	84	16	2.45	15
London; Westminster Abbey.....	1	9	77			
Emden	2	11	72			
St. Petersburg; Cent. Obs.....	1	13	68			
York; Museum	3	13	80	79 21	3.61	22
Calcutta; Alipore Obs.....	7	15	87			
Woodside; Welon on Thames.....	1	15	73			
Philadelphia, Frankfort Arsenal.	3	16	95			
Sheerness; Water Works.....	3	21	52			
Whitehaven; St. James Church...	10	24	66			
St. Petersburg; Cent. Obs.....	10	25	59			
Paris; Astronomical Obs.....	40	27	81	64 36	5.29	32
Dublin; Monkstown.....	6	27	64			
Oxford; Radcliffe Obs.....	8	34	59			
Copenhagen; Observatory..	4	36	67			
London; Westminster Abbey.....	1	46	52			
Chester; Lead Works.....	2	49	61			
Wolverhampton; Water Works..	3	55	69	58 42	7.68	46
York; Minster Spire	3	65	60			
Boston; St. Botolph Church.....	2	79	47			

Now the studies of Archibald and Stevenson have shown that for small altitudes the velocity of the wind increases very nearly as the square root of the altitude, if therefore our deficits are proportional to the winds they should be proportional to the numbers in the sixth column. This turns out to be so exactly the case that the formula

$$\text{Deficit} = 6 \text{ per cent} \times \sqrt{\text{altitude in meters}} \quad P$$

almost perfectly represents the deficits given in the fifth column.

Although the coefficient six thus closely represents the average of many years work, yet it cannot be safely adopted for any one locality, or even for any one year, since it involves the proportions of rain, snow and wind, that actually occurred during the observations above summarized; much less can it be adopted for any given month in the year or any given storm. On the other hand I conclude that for each wind and for each style of precipitation and for each style of gauge there must be a special coefficient to replace the figure six. In other words the coefficient must be known for each individual rainfall or snowfall.

It is not difficult to devise a method of ascertaining this coefficient at any moment. We have simply to establish two gauges at different heights, but near each other, and then, if they do not interfere with each other, and if the relative number of fine and large drops is the same at their respective elevations, and if the relative force of the wind at their mouths is known, we easily have the solution of the problem. If the gauges be placed above the roof of a flat building we shall get the rainfall on that roof instead of on the ground.

It would be best to directly measure the relative wind velocity for each gauge mouth by appropriate anemometers, or if this be not practicable, and if we have to assume some law such as Archibald's, connecting wind and altitude, then it would be an improvement to use three or more gauges at different altitudes so as to check this assumption, and determine the extent to which for any shower the deficit depends on the square or other function of the velocity, rather than on the simple velocity tself. But assuming, for simplicity, that only two gauges are used, our method of procedure would consist in measuring the catch of the gauges placed at different heights for each storm or each hour, and substituting these results as the known data in the single equation that connects these with the respective wind velocities; this equation is

$$\text{Catch of gauge} = \text{Catch of normal pit-gauges} \times (1 - k\sqrt{\text{altitude}})$$

or

$$C = P(1 - k\sqrt{h}.)$$

The values C_1 and C_2 for two altitudes h_1 and p_2 give us two

equations from which by elimination we determine P and k for each individual case. Of course the values of k are of minor importance to the climatologist and the ordinary observer who will be content to compute the value of P for each measured rainfall and will enter it in the proper column of his daily register as the corrected precipitation comparable in its scientific value with his corrected pressure or temperature.

The formula for this computation is easily deduced by elimination and may be put in the following form, where C_2 and h_2 belong to the upper gauge.

$$P = c_1 + \frac{1}{\sqrt{\frac{h_2}{h_1}} - 1}(c_1 - c_2)$$

The gauges being permanent as to their altitudes and so high that any winter snow will not materially change the h_1 and h_2, we may assume their ratio to be constant. Some one of the following combinations will naturally occur to the observer:

for altitude	1 and 4 2 and 8 3 and 12 etc.	$P = c_1 + (c_1 - c_2)$
for altitude	1 and 9 2 and 13 etc.	$P = c_1 + \frac{1}{2}(c_1 - c_2)$
for altitude	1 and 16 2 and 32 etc.	$P = c_1 + \frac{1}{3}(c_1 - c_2)$

Thus from measured rainfalls of 2.11 and 1.96 units caught in gauges at elevations of 1 and 4 units, we find the corrected rainfall to be 3.26 units, whereas, if for gauges at elevations of 1 and 16 units we had measured 2.11 and 1.60 we should have computed the true rainfall to be 2.28 units.

We have thus provided for the approximate correction of the rain gauge readings for the very large source of error introduced by the wind and the slowness of fall of the drops, and we find that the correction is, even for low gauges, quite as large as the quantities about which climatologists have had so much discussion; viz., the effect of forests and buildings, of the hour of the day, of the cultivation of the ground, of the sun spots, and

other suggested influences. None of these subjects can be properly studied until we correct the original catch of the gauge for the large error due to the influence of the wind. But the wind influence does not depend only on altitude, that is to say, the correction deduced for any pair of gauges at one spot cannot be transferred to a similar pair at a short distance, because the winds at that new position, during the falling of the rain, may have been different from those prevailing at the former location; a pair of gauges must be established and observed at every spot whose rainfall we would determine.

This leads me to remark that in such a case as is afforded by the valuable observations in the experimental rain field at Berlin, it is probable that the moderate differences in the horizontal distribution of rain are comparable with the differences due to the distribution of wind, so that the study of the uncorrected gauge readings is really a study into the effect of local winds on the catch of the gauge, and in general gauge readings do not show the geographical distribution of rain until they are corrected for the effect of the wind at the mouth of the gauge as for an instrumental error.

In the case of gauges placed above forests the measured quantities will increase as the forests grow taller, because the gauges come to be nearer the level and shelter of the tree tops; a gauge within the foliage of a tree should have a correction nearly the same as one near the ground, because of the diminished force of the wind in its neighhorhood.

Professors Joseph Henry and F. E. Nipher have advocated the use of "shielded gauges," and Börnstein has advocated "protected gauges," all so constructed that eddies about the mouths are largely diminished; such gauges therefore have smaller corrections than the simple cylinders, and a pair of such gauges mounted at different altitudes would give an excellent arrangement for studying the peculiarities of rainfall.

In the preceding I have assumed that the rain at the level of each gauge contains an equal proportion of the small drops due to spattering and drifting, but this is not true for very low gauges or for drifting snow, and a special discussion of that subject is reserved for future study.

WASHINGTON, August, 1889.

TORNADOES IN LOUISIANAA.

STATE TORNADO CHARTS.—LOUISIANA.

By LIEUT. JNO. P. FINLEY, Signal Service, U. S. A.

TABLE I.—*Tornadoes in Louisiana.*

Period of observation, 37 years, 1852–1888.

Total number of storms, 30.

Year of greatest frequency,—1869, 1879, 1880, 1882, 1883, 1888,—3 storms each.

Average yearly frequency,—2 storms.

Year in past ten (10) years, no report of storms,—1885.

Month of greatest frequency, April,—8 storms.

Day of greatest frequency, October 23d and November 14th,—2 storms each.

Hour of greatest frequency, 4 to 5 P. M.

Months without storms,—June, August, September and December.

Prevailing direction of storm movement, NE.

Region of maximum storm frequency, southeast and northwest portions.

TABLE II.—*A Chronological Table, showing the location, date and time of occurrence, and general character of formation and movement of Tornadoes in the State of Louisiana for a period of 35 years, from 1852 to 1888.*

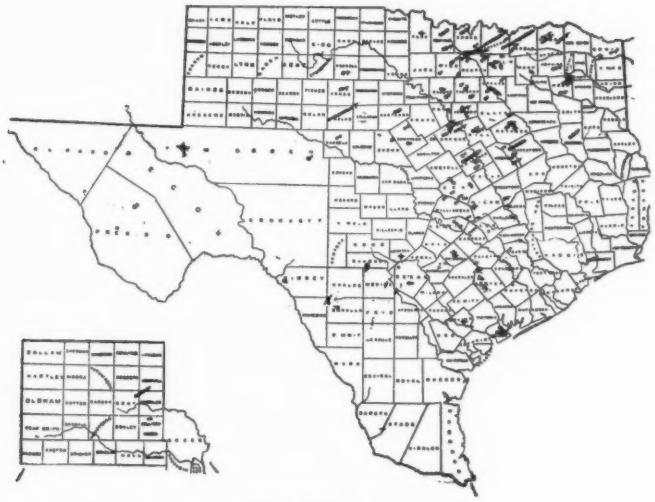
Parish.	Month and Day.	Year.	Time.	Direction.	Form of Cloud.	Width of Path in Feet.
DeSoto	January.	1852	.....	NE.	Funnel	400.
Richland	Spring.	1867	4 p m.	NE.	"	.....
St. John Baptist	April 26.	1869	Night.	NE.	.....	200.
Iberville	April 27.	1869	4 a. m.	E.	.....	.....
Caldwell	Fall.	1869	.....	E.	.....	.....
St. John Baptist	April.	1871	.....	.....	.....	.....
Winn	March 19	1875	8 p. m.	NE.	Funnel.	Narrow.
W. Feliciana	April 8.	1875	.....	.....	.....	.....
DeSoto	April 7.	1877	4 p. m.	NE.	.....	.....
Orleans	July 10.	1877	6:30 p. m.	SE.	Funnel.	.....
Caddo	February 10	1879	5 p. m.	NE.	"	300 to 500.
Rapides	November 14.	1879	Afternoon.	NE.	.....	750.
Ouachita	"	1879	Afternoon.	.....	.....	.....
Caddo	April 2.	1880	Afternoon.	NE.	Funnel.	2,500.
Sabine	November 8.	1880	5 p m.	NE.	.....	.....
DeSoto	November 9.	1880	4:30 p m.	NE.	Funnel.	500.
Tangipahoa	February 9.	1881	3:30 a m.	NE.	"	600 to 1,200.
Jefferson	April 19.	1882	6:30 p. m.	NE.	"	.....
Bienville	May 8.	1882	.....	NE.	"	300 to 600.
Caddo	May 12.	1882	.....	.....	.....	.....
Webster and Union	April 28	1883	4:10 p. m.	E.	Funnel.	1,200.
St. Landry	October 11.	1883	Night.	.....	Whirlwind.	.....
Tensas and Catahoula	October 29.	1883	2 a m.	NE.	Funnel.	600 to 1,200.
St. John Baptist	November 22	1884	5:27 p. m.	N.	.....	.....
Orleans	March 28.	1886	Evening.	.....	.....	.....
St John Baptist	February 26.	1887	11:50 a m.	E.	.....	.....
Iberia	May 10.	1887	Evening.	NE.	Funnel.	Very narrow.
St. John Baptist	October 22.	1888	4:35 a. m.	NE.	"	Narrow.
St. James	October 23.	1888	4:20 a. m.	NE.	.....	450.
Orleans	"	1888	2 p. m.	NE.	Funnel.	.....
						500

TABLE III.—*Relative frequency of Tornadoes by months and days, for Louisiana.*

The index figures to the right and above the dates show how many times tornadoes occurred on that day of the month.

Month.	Day of Month.	No. of Days.	Total No. of Tornadoes per month.
January	(—)	1	1
February	9, 10 and 26	3	3
March	19 and 28	2	2
April	2, 7, 8, 19, 26, 27, 28 and (—)	7	8
May	8, 10 and 12	3	3
July	10	1	1
October	11, 22, (23)², and 29	4	5
November	8, 9, (14)², and 22	4	5
(—) Blank	(—)²	(—)	2
Total		25	30

NOTE.—The blank (—) signifies date missing.



TORNADOES IN TEXAS.

STATE TORNADO CHARTS.—TEXAS.

By LIEUT. JNO. P. FINLEY, Signal Service, U. S. A.

TABLE I.—*Tornadoes in Texas.*

Period of observation, 39 years, 1850–1888.
Total number of storms,—96.
Year of greatest frequency, 1886,—28 storms.
Average yearly frequency,—5.7 storms.
Year in past (10) ten years, no report of storms,—none.
Month of greatest frequency, June,—29 storms.
Day of greatest frequency, June 19th,—13 storms.
Hour of greatest frequency, 4 to 5 P. M.
Months without storms, February, September and October.
Prevailing direction of storm movement, NE.
Region of maximum storm frequency, north central portion.

TABLE II.—*A Chronological Table, showing the location, date and time of occurrence, and general character of formation and movement of Tornadoes in the State of Texas for a period of 39 years, from 1850 to 1888.*

County.	Month and Day.	Year.	Time.	Direction.	Form of Cloud.	Width of Path in Feet.
Shelby	December 29.	1850	8 p. m.	NE.	Funnel.	900 to 1,320.
Dallas	May 5.	1853	4 p m.	NE.	"	
Tarrant	May 26.	1867	8 p m.	ENE.		750.
Navarro	March 31.	1875	Afternoon.			
Caldwell	January 26.	1876	9 p m.			
Kendall	May 26	1877				
Austin	June 22.	1877		NE.		
Calhoun	July 11.	1877	Afternoon.		Funnel.	75 to 200.
Presidio	April 20.	1878	3 p. m.	NE.	"	
Navarro	April 23.	1878	2:10 a. m.	NE.	"	600 to 800.
Wise	May 2.	1878	6:45 p. m.	NE.		
Calhoun	June 24.	1878	7:10 a. m.	SE.	Funnel.	
Dallas	April 15.	1879	2 p. m.	SE.	Cone.	900 to 3,500.
Denton	April 27.	1879	1 p. m.			
Collin	July 28.	1879	Evening.	S.		
Navarro	July 29.	1879	Afternoon.	E.		
Caldwell	January 26.	1880				
Milam	April 29.	1880	Afternoon.			
Fannin	May 28.	1880	10 p. m.	NE.	Funnel.	500 to 800.
Goliad	August 15.	1880				
McLennan	May 28.	1881	Afternoon.	NE.		
McLennan	"	1881	Afternoon.	NE.		
Fannin	June —.	1881		NE.		
Clay	June 12.	1882	7:20 p. m.		Funnel.	
Bell	April 27.	1883	About 4:30 p. m.	SE.	"	600.
Grayson	May 17.	1883	9:30 a. m.	NE.	"	
Hunt	June 2	1883	7:15 p. m.	SE.		
Collin	June 9.	1883		SE		
Tarrant	June 26.	1883		NNE.		
Tarrant	April 18.	1884	9:20 a. m.	E 10° N.	Funnel.	90.
Tom Green	April 28.	1884	p. m.	NE.		
Kinney	April 30.	1884	6 p. m.	S 20° E.	Funnel.	
Montague	"	1884	2:30 p. m.	NE.	Balloon.	450
Eastland	June 8.	1884	4:30 p m.		Funnel.	1,320.
Limestone and Freestone	June 10.	1884	10 a. m.	NE.	"	600.
Dallas	August 23.	1884	Afternoon.	SW. ?	"	
Cooke	March 11.	1885	4 p. m	NE.	"	1,320 to 2,640.

TABLE II.—*Continued.*

County.	Month and Day.	Year.	Time.	Direction.	Form of Cloud.	Width of Path in Feet.
Grayson	March 11.	1885	8 p. m.	E.	Funnel.	150.
Denton	"	1885	5 p. m.	NE.	"	.....
McLennan	April 19.	1885	1 p. m.	NE.	"	90 to 300.
Grayson	April 21.	1885	5:35 p. m.	NE.	.....	.....
Wood	April 22.	1885	p. m	NE.	Funnel.	.....
Limestone	"	1885	1 p. m.	NE.	"	2,640.
Hill	"	1885	10 a. m.	NE.	"	300 to 400.
Cass	November 5.	1885	Evening.	NE.	Whirlwind.	90.
Cherokee	November 6.	1885	5 p. m.	NE.	Funnel.	900.
Wise	April 14.	1886	10:30 p. m.	NNE.	"	1,200.
Wise	"	1886	Between 9 and 10 p. m.	.....	.....	.....
Wise	"	1886	10:30 p. m.	NNE.	Too dark to see.	1 200.
Hamilton	April 24.	1886	2 p. m.	Easterly.	Funnel.	Narrow.
Bell	April 25.	1886	6 p. m.	SE. ?	"	150 to 300.
Tarrant	"	1886	7 p. m.	NE.	.....	.....
Runnels	April 28.	1886	2 a. m.	NE.	Funnel.	200.
Calhoun	June 8.	1886	Afternoon.	.....	"	.....
Cooke	June 16.	1886	4 p. m.	NE.	Basket.	.....
Bell	"	1886	5 p. m.	NE.	Funnel.	.....
Bowie	"	1886	Afternoon.	NE.	"	.....
Williamson	June 19.	1886	7:15 p. m.	NE.	Cone.	1,320.
Williamson	"	1886	3:30 p. m.	NE.	Funnel.	1,320 to 2,640.
Williamson	"	1886	7:15 p. m.	NE.	"	1,320 to 2,640.
Travis	"	1886	6:45 p. m.	SE. ?	Dense roll'g mass.	2,640 to 5,280.
Bell	"	1886	6:10 p. m.	NE	.....	.....
Bosque	"	1886	3:30 p. m.	NE.	.....	5,280.
Bastrop	"	1886	About 5 p. m.	Easterly.	.....	.....
Milam	"	1886	4:30 p. m.	Easterly.	Funnel.	2,640.
Limestone	"	1886	6:30 p. m.	NE.	"	.....
Parker	"	1886	3:40 p. m.	Easterly.	.....	5,280.
Brown	"	1886	6 p. m.	Easterly.	.....	.....
Ellis	"	1886	6 p. m	Easterly.	.....	5,280 to 8,000.
Dallas	"	1886	Afternoon.	NE.	Funnel.	.....
Comanche	July 12.	1886	5 p. m.	NE.	"	.....
Grayson	August 18.	1886	3:30 p. m.	Easterly.	"	1,320 to 2,640.
Bexar	August 24	1886	5 p. m.	ESE.	"	5,280.
Comanche	"	1886	8:30 p. m.	ESE.	.....	5,280 to 10,500.
Lamar	January 22.	1887	7 p. m.	NE.	Funnel.	2,640.

TABLE II.—*Concluded.*

County.	Month and Day.	Year.	Time.	Direction.	Form of Cloud.	Width of Path in Feet.
Bosque	January 22.	1887	4 a m	NE.	Funnel.	2,640.
Denton	March 26.	1887	5:30 p. m.	NE.	Inverted cone.	1,320.
Lamar	April 22.	1887	8:30 a. m.	NE.	Funnel.	800 to 1,200.
Bosque	April 29.	1887	9 p. m.	SE.	Inverted cone	Narrow.
Cooke	"	1887	9 p m.	NE.	Cone.	2,640.
Johnson	April 30.	1887	1:30 p. m.	SE.	Funnel.	1,320.
Limestone	May 2.	1887	4 p. m.	NE.	.....	Narrow.
McLennan	June 6.	1887	5 p m.	Easterly.	Funnel.	150.
Bell	June 21.	1887	10 p. m.	SE.	.....	1,320.
Johnson	July 5.	1887	3:30 p. m.	SE.	Funnel.	2 640.
Robertson	July 22.	1887	4:30 p. m.	Easterly.	"	1,200.
Jones	July 26.	1887	4 p. m	Easterly.	"	800.
Haskell	"	1887	Afternoon.	ENE	.....	300 to 900.
Wood	November 26.	1887	Night.	ENE.	.....	2.640.
Lamar	May 23.	1888	afternoon.	NE	Funnel.	900.
Navarro	"	1888	Night.	NE.	.....	2,640.
Hopkins	"	1888	Afternoon.	NE.	Funnel	1 320
Wheeler	May 25.	1888	4:10 p. m.	NE.	"	700 to 1,200.
Hill	May 27.	1888	7 a. m.	NE.	.....	1,320
Montague	June 23.	1888	2 p m	Easterly.	Funnel.	2 250.
Taylor	November 7.	1888	7:40 p. m.	ENE.	"	240 to 375.

TABLE III.—*Relative frequency of Tornadoes by months and days, for Texas.*

The index figures to the right and above the dates show how many times tornadoes occurred on that day of the month.

Month.	Day of Month.	No. of Days.	Total No. of Tornadoes per month.
January	(22)^{2} and (26)^{2}	2	4
March	(11)^{3}, 26 and 31	3	5
April	(14)^{3}, 15, 18, 19, 20, 21, (22)^{4}, 23, 24, (25)^{2}, (27)^{2}, (28)^{2}, (29)^{3} and (30)^{3}	14	26
May	(2)^{2}, 5. 17, (23)^{3}, 25, (26)^{2}, 27 and (28)^{3}	8	14
June	2, 6, (8)^{2}, 9, 10, 12, (16)^{3}, (19)^{13}, 21, 22, 23, 24, 26 and (—)	14	29
July	5, 11, 12, 22, (26)^{2}, 28 and 29	7	8
August	15, 18, 23 and (24)^{2}	4	5
November	5, 6, 7 and 26	4	4
December	29	1	1
Total		57	96

NOTE.—The blank (—) signifies date missing.

DISTRIBUTION OF AVERAGE WIND VELOCITIES IN THE UNITED STATES.

INVESTIGATED BY DR. FRANK WALDO.

(CONTINUED FROM SEPTEMBER NUMBER.)

SECTION II. AVERAGE WINDS FOR GROUPS OF STATIONS IN THE UNITED STATES.

The average monthly wind velocities for individual observing stations, on which the present paper is based, are to be found in the Chief Signal Officer's annual report for 1885, and also in the the *Meteorologische Zeitschrift*, for August, 1888, and it has not been considered necessary to reproduce this table here. In nearly every case the averages are for the time from the establishment of the station down to Jan. 1, 1885.

In the present section, grouped stations are to be principally considered, but in the accompanying Table I, some data are given for the individual stations. In this table, column 1 contains the numbers of the various groups of stations; column 2 contains the names of the stations in these groups; column 3 gives the elevations of the anemometers above street level at the various stations (on Jan. 1, 1887); column 4 gives the difference, in miles per hour, between the months of greatest and least wind; column 5 contains the ratio between the winds for the months of maximum and minimum.

In order to represent the annual march of the wind velocities more accurately than can be found from single stations, I have combined these latter into the groups given in Table I in which each group has special characteristics of location or exposure.

*It may be mentioned just here that a chart of the data maximum ÷ minimum will be described later on.

TABLE I.

Group.	Name of Station.	Elevation in meters of anemom. above street.	Max. month.— Min. month. m. p. h.	Max. month m p. h Min. month, m. p. h.
	Eastport	17.3	7.1	2.25
	Portland	26.5	3.3	1.57
	Boston	55.2	4.2	1.59
I.	New Haven	38.1	3.6	1.62
	New London	19.8	3.8	1.72
	New York	51.2	4.1	1.55
	Burlington	24.3	3.3	1.62
II.	Springfield			
	Albany	33.2	4.3	1.96
	Philadelphia	53.3	4.2	1.55
III.	Baltimore	26.2	2.1	1.43
	Washington	21.6	3.7	1.77
	Block Island	12.5	7.3	1.71
	Barnegat	13.4	5.3	1.54
	Cape May	16.1	6.7	1.68
IV.	Sandy Hook	13.7	5.8	1.52
	Del'w're Breakw'r	11.2	7.2	1.76
	Cape Henry	9.4	4.8	1.49
	Chincoteague	8.5	4.8	1.50
	Lynchburg	21.0	2.5	1.96
	Charlotte	20.7	2.1	1.47
V.	Augusta	17.1	1.8	1.58
	Jacksonville	24.7	2.2	1.39
	Sanford	14.3	3.8	1.81
	Montgomery	23.7	2.6	1.67
	Hatteras	9.2	4.0	1.31
VI.	Kitty Hawk	8.8	3.9	1.32
	Ft. Macon	14.9	3.1	1.27
	Smithville	12.5	2.5	1.30
	Wilmington	19.8	3.4	1.60
VII.	Charleston	21.9	1.7	1.24
	Savannah	21.3	2.5	1.46
	Pensacola	16.1	2.2	1 33
	Mobile	28.6	1.8	1.35
	Vicksburg	20.7	3.1	1.82
	New Orleans	29.5	3.1	1.56
	Shreveport	18.6	2.7	1.73
VIII.	Ft. Smith	16.7	3.0	1.83
	Little Rock	21.9	3.0	1.79
	Palestine	28.9	4.4	1.65
	San Antonio	12.8	1.8	1.47
	Brownsville	11.5	4.6	2.00
	Rio Grande City	10.0	4.8	1.83
	Cedar Keys	14.6	4.2	1.41
	Key West	19.2	4.5	1.62
IX.	Indianola	16.1	6.9	1.73
	Galveston	23.1	2.9	1.55
	Chattanooga	22.8	3.4	1.77
	Knoxville	25.9	3.4	1.81
	Memphis	23.4	2.7	1.68
	Nashville	27.1	2.2	1.67
	Louisville	35.3	3.6	1.67
	Indianapolis	24.3	3.1	1.72
X.	Cincinnati	47.8	3.1	1.72
	Columbus	25.6	4.4	1.88
	Pittsburg	42.0	3.1	1.70
	Cairo	25.0	5.1	2.04
	Springfield	28.0	4.7	1.77
	St. Louis	63.4	4.3	1.57
	Buffalo	32.9	5.5	1.83
	Oswego	26.5	4.9	1.82
	Rochester	49.1	4.7	1.67
	Erie	23.7	5.8	1.82
XI. a	Cleveland	25.6	4.4	1.64
	Sandusky	29.8	4.5	1.44
	Toledo	35.0	3.1	1.47
	Detroit	35.6	2.8	1.45
XI. a	Alpena	21.6	3.1	1.44
	Escanaba	15.2	2.8	1.36
	Grand Haven	25.9	4.0	1.49
	Mackinaw City	11.8	3.6	1.43
XI. b	Marquette	21.0	2.9	1.43
	Port Huron	32.9	3.4	1.47
	Chicago	46.6	2.8	1.41
	Milwaukee	46.3	4.4	1.52
	Duluth	21.6	2.6	1.42
	St. Paul	37.8	2.5	1.35
	La Crosse	23.4	2.5	1.40
	Davenport	25.9	4.1	1.64
	Des Moines	19.2	3.6	1.78
	Dubuque	18.9	2.8	1.78
XII.	Keokuk	22.3	3.9	1.63
	Leavenworth	20.1	3.9	1.74
	Omaha	27.4	4.0	1.58
	Moorbead	17.9	2.5	1.27
	St. Vincent	7.3	2.7	1.36
	Assiniboine	10.9	3.2	1.37
	Ft. Benton	19.8	2.4	1.41
	Ft. Custer	9.4	2.2	1.34
	Helena	18.6	2.1	1.46
	Ft. Shaw	8.2	5.8	1.82
XIII.	Ft. Maginnis	7.9	5.8	1.62
	Deadwood	18.6	1.0	1.29
	Cheyenne	48.7	4.8	1.59
	Denver	33.2	1.7	1.30
	West Las Animas	9.1	5.5	1.89
	Ft. Bennett	6.1	3.5	1.56
	Huron	11.8	3.1	1.33
	Yankton	12.8	4.9	1.69
	Bismark	15.2	3.4	1.43
	Ft. Buford	9.1	3.4	1.49
XIV.	North Platte	13.4	4.8	1.54
	Dodge City	16.7	4.6	1.45
	Ft. Elliott	7.3	4.2	1.76
	Ft. Sill	7.3	5.3	1.63
	Ft. Concho	6.7	3.8	1.42
	Ft. Davis	7.0	2.7	1.61
	Ft. Stockton	7.6	5.3	1.77
	Santa Fe	10.9	2.9	1.49
XV.	El Paso	10.9	2.1	1.91
	Ft. Apache	10.6	2.9	1.57
	Ft Grant	7.9	2.9	1.48
	Prescott	7.9	3.4	1.74
	Winnemucca	11.5	1.7	1.21
XVI.	Salt Lake City	27.1	2.6	1.67
	Boisé City	13.7	2.4	1.69
	Lewiston	14.9	1.3	1.62
XVII.	Dayton	8.5	1.7	1.37
	Spokane Falls	14.6	2.6	1.74
XVIII.	Ft. Canby	7.6	9.8	2.72
	Tatoosh Island	7.6	12.2	3.39
	Olympia	16.4	1.6	1.57
	Portland	28.0	1.8	1.44
XIX.	Roseburg	14 6	1.5	1.80
	Red Bluff	15.2	3.6	1.71
	Sacramento	21.3	3.5	1.85
	Los Angelos	34.7	1.4	1.30
	San Diego	48.7	1.8	1.36
	St. Michaels	7.9	4.2	1.42
	Sitka	32.9	6.1	1.99
	Unalashka	7.9	6.8	1.77
	Behring's Is.	3.0	7.2	1.77

In this grouping the following general divisions are followed:

I. New England sea coast cities;
II. Central New England;
III. Middle Atlantic States, inland;
IV. Middle Atlantic States, exposed coast;
V. S. E. U. S. inland;
VI. Carolina coast exposed;
VII. Carolina coast cities;
VIII. Southern States;
IX. Gulf Coast;
X. Ohio valley;
XI*a*. Lower Lakes;
XI*b*. Upper Lakes:
XII. Upper Mississippi:
XIII. Eastern base of Rocky Mountains;
XIV. Great Plains of Missouri and Arkansas Rivers.
XV. Southern Plateau;
XVI. Central Plateau;
XVII. Northern Plateau;
XVIII. N. W. U. S. coast;
XIX. N. W. U. S. inland.

In the following Table II the first column contains the numbers I, II, etc., for the identification of the groups; the second column, the number of stations used; the third column, the average elevation in meters, of the station barometers above sea level; the fourth column, the average elevation in meters, of the anemometers above the street as found on Jan. 1, 1887; the succeeding columns contain the average number of miles per hour of wind for each month and the year, for that region, as shown by the simple mean of the velocities observed at the stations used, no refinements being attempted in the way of assigning different weights to the observations at the various stations.

It will be noticed that a number of single stations for the Pacific coast are given at the end of the groups. This is because they had characteristics which would not allow of their being combined with other stations, but still it was desirable to include them in this paper.

TABLE II.

Group.	No. of Stations.	Av. elevat'n above sea level.	Av. elevt'n of Anemomet'r above street level.	January.	February.	March.	April.	May.	June.	July.	August	September.	October.	November.	December.	Year.
		---Meters.---														
I	6	31	35	9.3	9.9	10.6	9.4	8.0	7.0	6.6	6.2	7.3	8.3	9.4	9.2	8.4
II	3	.....	.....	7.1	7.2	7.8	7.5	6.4	5.6	5.0	4.5	5.3	6.0	7.0	6.9	6.4
III	3	34	34	7.4	8.0	9.1	8.7	7.1	6.9	6.5	5.8	6.3	6.7	7.1	7.4	7.3
IV	7	6	11	14.9	15.2	16.3	14.6	12.7	11.7	10.6	10.5	12.9	14.0	15.1	15.1	13.7
V	6	.....	.....	5.2	5.8	6.4	6.0	5.1	4.9	4.4	4.2	4.7	5.0	5.3	4.7	5.1
VI	3	3	11	14.2	15.3	15.7	15.4	13.9	13.5	12.4	12.4	13.7	14.6	13.9	14.1	14.1
VII	4	17	19	7.4	8.2	9.2	9.6	8.3	8.1	7.6	6.8	7.2	7.1	7.2	7.3	7.8
VIII	11	.....	19.5	6.7	7.7	7.5	7.6	6.7	5.1	5.9	5.0	5.2	5.7	6.3	6.5	6.4
IX	4	8	18	11.1	11.3	11.7	12.1	10.5	9.5	8.6	8.1	9.2	10.6	11.3	11.0	10.4
X	12	198	33	7.2	7.7	8.4	7.8	7.2	6.5	5.3	4.9	5.5	5.9	6.9	7.1	6.6
XI*a*	8	189	32	10.9	10.9	11.0	10.2	8.7	8.1	7.4	7.1	8.4	9.6	11.0	11.1	9.5
XI*b*	9	197	27	9.7	10.2	10.2	10.0	9.0	7.5	7.7	7.6	9.1	9.9	10.1	10.1	9.3
XII	10	243	22	8.6	9.2	9.3	9.4	8.6	7.5	6.5	6.5	7.4	7.9	8.2	7.8	8.0
XIII	10	1227	18	7.6	7.6	8.4	8.8	8.4	7.7	7.4	6.9	7.3	8.6	8.3	8.1	8.1
XIV	10	571	11	9.1	9.6	10.9	12.3	11.8	10.7	9.2	8.9	9.7	9.9	9.2	8.6	10.0
XV	7	1487	9	6.0	6.7	7.5	8.3	8.0	7.6	6.5	5.7	6.1	6.2	5.7	5.9	6.7
XVI	3	1164	17	5.8	6.3	7.0	7.1	7.0	6.8	6.1	6.1	5.9	5.8	5.1	5.4	6.2
XVII	3	444	12	3.9	4.3	4.6	5.2	4.8	4.4	4.6	4.0	3.7	4.0	3.6	3.8	4.3
XVIII	2	40	8	15.9	14.2	9.4	10.1	10.0	8.5	5.4	7.8	9.2	11.6	14.6	14.8	11.0
XIX	5	61	19	5.4	5.6	5.7	5.7	5.5	5.4	4.9	3.9	4.0	4.4	4.0	4.4	5.0
Los Angeles	.....	.....	.....	5.7	6.6	5.5	5.5	5.4	5.2	4.8	4.6	4.7	4.8	4.9	5.1	5.2
San Diego	.....	.....	.....	5.3	6.1	6.5	6.8	6.7	6.4	6.4	6.1	6.0	5.5	5.0	5.1	6.0
St. Michaels	.....	.....	.....	13.9	12.9	12.9	11.9	10.0	10.4	11.3	12.2	12.5	14.2	13.9	12.0	12.3
Sitka	.....	.....	.....	10.3	9.5	9.5	8.7	8.7	6.9	7.3	6.2	7.6	9.0	11.2	12.3	8.9
Unalashka	.....	.....	.....	12.4	15.6	13.4	12.9	11.0	11.0	9.8	8.8	12.6	11.7	12.3	13.7	12.1
Behring's Is	.....	.....	.....	16.0	16.6	14.6	13.0	12.1	11.0	9.7	9.4	10.3	15.5	13.8	13.3	12.9

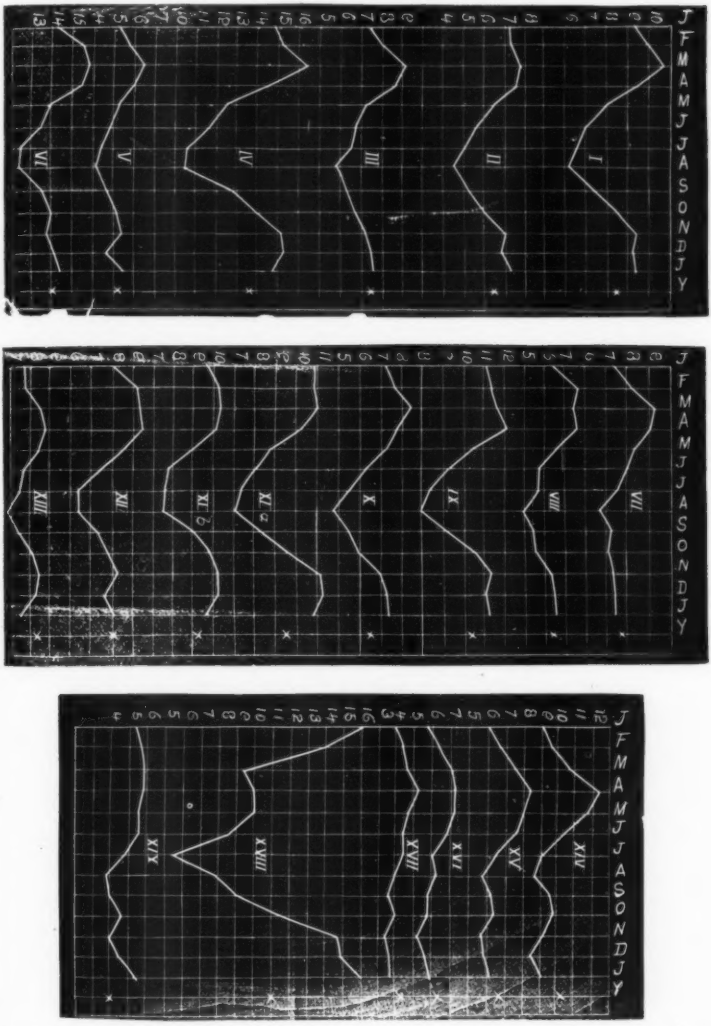
In order to bring out more clearly the characteristic "annual march" of the separate regions represented by the grouped data of the preceding table, there is given here a graphical presentation of each of the separate groups.

In the graphical table the vertical argument signifies anemometer miles on a scale of one mile to each division; the horizontal argument is months, the separate months being designated by the first letter of each; the last letter, Y, signifying the year, and under this is found the annual mean shown by a x. The numerals I, II, etc., are used as in the preceding numerical table.

In general in the eastern part of the United States there is a *principal* maximum and minimum in March and August respectively, with a *secondary* fall maximum and winter minimum; this latter however is somewhat variable and does not take place for the same months in the different regions.

In the Lake region there is considerable irregularity in the times of maximum and minimum, for the single stations, but

CHART I.*—*Annual March of Wind Velocities.*



*NOTE.—In the Charts I and II, it will be noticed that the figure 9 is reversed.

the average curves show for the Lower Lakes very little difference in the wind velocities from November to March inclusive, but with a scarcely perceptible winter minimum; while for the Upper Lakes the mean velocities for the months October to April inclusive are nearly constant, but with a slight January minimum; the principal minimum occurring in August. The Lower Lakes region seems to have a little more wind in winter and a little less in summer than the Upper Lakes region.

As we look westward we notice that the spring maximum gradually changes from March to April, and this change is first noticed for the Mississippi River stations, while the Upper Lakes region shows that the winds there are about the same for these two months. West of the Mississippi the month of April has the maximum amount of wind for the average of the regions almost without exception, but a glance at the table of individual stations shows that by no means the regularity exists for these stations that we find for those of the Eastern United States. For the stations of the Mississippi Valley and the Great Plains the minimum occurs in August, but for those further west, but not on the coast, the minimum has a tendency to occur a little later in the fall.

On the Southern Pacific Coast, the maximum occurs in the spring (in Lat. 34° Long. 117° W.) in April, and the minimum in November. Further north, at San Francisco, the maximum occurs in July and the minimum in November. Still further north (Lat. 47° Long. 125° W.) the maximum occurs in January, and the minimum in July. And further north and west, in Alaska, at Sitka (Lat. 57° Long. 135° W.) the maximum in December and minimum in August; at Lat. 54° Long. 166° maximum in February, minimum in August; at St. Michaels, (Lat. 64° Long. 162°) maximum in October, minimum in May. We have not this great range of Latitude for the Atlantic coast stations, and therefore cannot be sure that this same irregularity does not exist on our Eastern coast, but it is probable that nearly the same annual march is found along the Atlantic coast, that is found for the Eastern United States stations.

SECTION III. SECULAR VARIATION OF WIND VELOCITIES FOR SELECTED STATIONS.

Representative stations were selected for some different parts of the United States and the wind movement, for *each month*, from the time of establishment up to 1887, was tabulated in such a form as to be convenient for discussion. The stations selected were, Boston, Albany, Augusta (Ga.), Key West, Indianapolis, Grand Haven, Milwaukee, Cairo, Dodge City, Pike's Peak, Salt Lake City and San Francisco. The monthly wind movement for these stations, for the period up to July, 1880, was kindly furnished by the Chief Signal Officer; all subsequent data were abstracted by the writer from the Signal Service publications.

As this work progressed, it became evident that the full value of such an investigation as was intended, could not be attained, on account of the numerous changes* in the locations of the anemometers under consideration; and, as probably no meteorological instrument gives such varying results with change of position as the wind measure, we cannot, without additional labor, connect series of observations made under different exposures.

These data, on account of their non-homogeneity, require more time for discussion than can at present be given, and I will, therefore, reserve their detailed study for a future contribution to the subject of wind velocities. There are, however, a few points that can be given now that are of interest.

In the following Table III there is given the *annual amounts of wind* and the *elevation of the anemometer above the street*, for each of the stations mentioned above. The wind amounts are given in *thousands of miles* (for instance, Boston in 1872 had 58,000 miles of wind), and the anemometer elevations are given in meters and tenths. A slight inspection of this table shows that most of the stations have been changed in location, and some of them as many as three or four times. Both the new and old anemometer elevation are given opposite the year when a change was made.

*However these changes will probably prove of great value in the determination of the law of increase of wind with elevation.

TABLE III.

Year.	I. Boston.		II. Albany.		III. Augusta (Ga.)		IV. Key West.		V. Indianapolis.		VI. Grand Haven.		VII. Milwaukee.		VIII. Cairo.		IX. Pike's Peak		X. Dodge City.		XI. Salt Lake City.		XII. San Francisco.		Year.
	Annual Am't of Wind. 1 = 1000 miles.	Elevation of Anemometer above street. Meters.	Annual wind.	Elevation of anem.	Annual wind.	Elevation of anem.	Annual wind.	Elevation of anem.	Annual wind.	Elevation of anem.	Annual wind.	Elevation of anem.	Annual wind.	Elevation of anem.	Annual wind.	Elevation of anem.	Annual wind.	Elevation of anem.	Annual wind.	Elevation of anem.	Annual wind.	Elevation of anem.	Annual wind.	Elevation of anem.	
1872	58	20.4	..	....	26	18.0	80	....	..	23.2	...	25.9	...	34.1	53	20.7	...	...	...	....	..	....	81	37.2	1872
1873	61	20.4	..	....	32	18.0	95	17.1	54	23.2 25.9	...	25.9	78	34.1	63	20.7	...	4.6	...	....	..	....	84	37.2	1873
1874	68	20.4	69	14.5	35	18.0	93	17.1	51	25.9	98	25.9	91	34.1	..	20.7	...	4.6	...	....	..	16.2	84	37.2	1874
1875	81	20.4 54.2	56	14.5	35	18.0	86	17.1	56	25.9	100	25.9	95	34.1	61	20.7	180	4.6	85	9.4	45	16.2	86	37.2	1875
1876	93	54.2	58	14.5	35	18.0	88	17.1	51	25.9	106	25.9	95	34.1	64	20.7	188 (?)	4.6	120	9.4	42	16.2	82	37.2	1876
1877	88	54.2	62	14.5	34	18.0	83	17.1	43	25.9	94	25.9	92	34.1	65	20.7 25.0	180	4.6	121	9.4	51	16.2	81	37.2	1877
1878	92	54.2	69	14.5	36	18.0 17.7	94	17.1	49	25.9	89	25.9	97	34.1 46.3	65	25.0	176	4.6	115	9.4	49	16.2	79	37.2	1878
1879	89	54.2	70	14.5	37	17.7	90	17.1	46	25.9	97	25.9	104	46.3	60	25.0	188	4.6	115	9.4 11.9	50	16.2	79	37.2	1879
1880	86	54.2	59	14.5 24.1	28	17.7	84	17.1	56	25.9	92	25.9	111	46.3	68	25.0	185	4.6	103	11.9	49	16.2	83	37.2	1880
1881	84	54.2	51	24.1	38	17.7	79	17.1	49	25.9 24.4	83	25.9	90	46.3	64	25.0	170	4.6	111	11.9	40	16.2	83	37.2	1881
1882	88	54.2	50	24.1	33	17.7	78	17.1 17.7	49	24.4	99	25.9	103	46.3	67	25.0	...	4.6	103	11.9	46	16.2	86	37.2	1882
1883	83	54.2	54	24.1	30	17.7	77	17.7	47	24.4	100	25.9	108	46.3	74	25.0	...	4.6	104	14.3	42	16.2	81	37.2	1883
1884	93	54.2 55.2	54	24.1 33.2	31	17.7	86	17.7	51	24.4	94	25.9	97	46.3	69	25.0	172	4.6	114	14.3	49	16.2	79	37.2	1884
1885	104	55.2	60	33.2	34	17.7	85	17.7	49	24.4	94	25.9	98	46.3	68	25.0	168	4.6	101	14.3	38	16.2	79	37.2	1885
1886	103	55.2	55	33.2	34	17.7	94	17.7 19.2	48	24.4	93	25.9	93	46.3	67	25.0	185	4.6	93	14.3 16.8	43	16.2 27.1	78	37.2	1886

These stations were selected merely because they appeared to be representative of different parts of the country, and it may safely be concluded that the number of changes in the location of these stations represents fairly well the changes in other stations, so that the elevations of the anemometers given in Table I cannot be used with any degree of certainty, in applying them to the average wind velocities given here. It will be noticed that when a change is made in an anemometer exposure, it is usually done by *increasing* the elevation of the instrument, so that averages of wind velocity will, in most cases, refer to some lower average elevation than that given in the table for January 1, 1887.

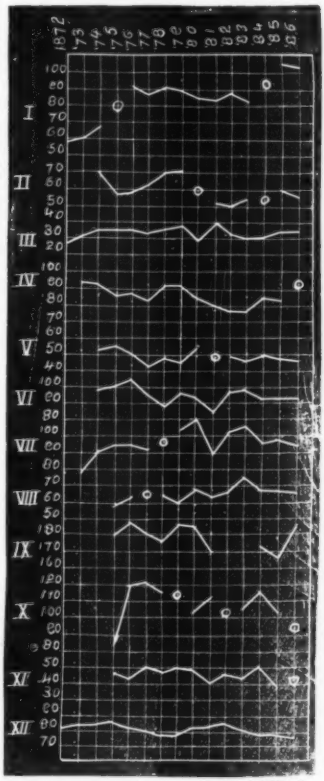


CHART II.—*Annual amounts of Wind.*

In order to show more clearly the secular variations shown by the data in the foregoing table, these data have been given in graphical form. In this graphical table the vertical argument is in *thousands of miles*, and the horizontal argument gives the year. In drawing the curves, the years when changes have been made in anemometer elevation have not been connected with the preceding and succeeding years: a ○ shows the position on the chart which represents the wind for that year as found by uniting the observations for the two different exposures. Where the change is only a fraction of a meter I have assumed that the observation in the two positions can be combined, as the difference in the amounts of wind in the two elevations must be

very small. The number I, II. etc., of the tables of Section III have no connection with those of Section II.

Of course in examining these curves for maxima and minima, only those in which the anemometer has remained practically unchanged can be legitimately used; but the connected portions of the broken curves can be utilized in determining whether the amount of wind is on the increase or decrease.

The following little table contains the dates of what may be taken as maxima and minima as shown by the preceding curves, but the question is one depending so much on judgment that the dates assigned can only be considered approximate; and, too, the range is in some cases so small, that the reader may not agree at all with the times of maxima and minima assigned by the writer.

The maxima are given in large figures, and the minima in small.

Boston.	Albany.	Augusta.	Key West.	Indianapolis.	Grand Haven.	Milwaukee.	Cairo.	Salt Lake City.	San Francisco.
1872	75	72	75	**74**		73			**74**
1877	**79**	**77**	**79**	77	**76**	**78**(?)	79	**73**	78
1881	82(?)	83	82(83)		81	86	**83**	82	**82**
									86

From these dates it is seen that a period of about nine years is *not improbable;* and that for the eastern part of the United States there was a minimum about 1873, a maximum about 1878 and a second minimum about 1882.

Cairo and Indianapolis, both inland river stations, have a reversal of this as also does San Francisco. Dodge City evidently had a maximum about 1877, but the frequent changes in anemometer elevation prevent fixing other phases.

[TO BE CONTINUED.]

INTERMITTENT FEVER AND TEMPERATURE.

Some very interesting studies of intermittent fever in its relation to atmospheric temperature have been made by Dr. H. B. Baker, Secretary of the State Board of Health of Michigan, from which he arrives at the following conclusions:

1. Intermittent fever is proportional, directly or inversely, to the average daily range of atmospheric temperature.

2. The controlling cause of intermittent fever is exposure to insidious changes, or changes to which one is unaccustomed, in the atmospheric temperature.

3. In the mechanism of the causation of intermittent fever, the chief factor is the delay in the reaction from exposure to cool air; this delay, extending to a time when greater heat loss should occur, results in the abnormal accumulation of heat in the interior of the body, and in disturbing nervous action—the chill; and the final reaction is excessive because of the accumulation of heat, and sometimes because it occurs at the warmest part of the day.

4. The fever is the excessive reaction from the insidious influence of exposure to cool air; and it is periodical because of the periodicity of nervous action, and because the exposure and consequent chill are periodical, owing to the nightly absence of the warmth to the sun.

5. Residence in valleys or on low land through which, or upon which cold air floats at night, and thus causes insidious changes in the atmospheric temperature, favor intermittent fever.

6. In our climate, those measures (such as drainage) which enable the soil to retain the warmth during the night, and thus reduce the daily range of temperature immediately over such soil, tend to decrease intermittent fever among the residents thereon.

7. In the cure and prophylaxis of intermittent fever, those remedies are useful which lessen torpidity and tend to increase the power of the body to react promptly to insidious changes in the atmospheric temperature.

8. The slowness of the pulse, and other indications of torpidity associated with retention of bile, or with certain disturbances of the functions of the liver, are well known; but so far as known

to the writer, these conditions have not hitherto been considered as causative of the fever in the manner herein suggested.

The health statistics of Michigan prove conclusively the first of these propositions, not only with regard to intermittent, but to remittent fevers, as well.

The remaining propositions would seem to give undue prominence to what, it must be conceded, is but one of many factors in the causation of periodic fevers.

An elevated temperature has, no doubt, much to do in bringing about those states of the system which are present in these diseases, but the fact that intestinal disorders and digestive derangements are most common at that season of the year when cases of intermittent and remittent fevers are most abundant has a significance that should not be overlooked.

The "insidious changes" of atmospheric temperature could not of themselves work such disastrous results in a perfectly healthful organism like the body of man which has a wide range of adaptability to external influences. For such a result to follow "a delay in reaction from exposure to cool air," as assumed by Dr. Baker to be the starting point for the morbid process, the subject must be presumed to be in an abnormal state already, otherwise no such delay in reaction would occur.

Is not the essential factor rather to be looked for in malnutrition or imperfect assimilation, together with retained effete products in the excreting organs, whereby either directly or by furnishing a suitable culture field for deleterious bacteria, the blood is poisoned and in turn affects the nervous system as is evidenced by the chill and disturbance of the heat centre.

A high atmospheric temperature with rapid change to a lower, especially when attended by an excess of moisture, would greatly favor such results by rendering the circulation sluggish, and causing congestion of the abdominal viscera, as well as by hastening the decomposition of food products. But that such elevated temperature or high "average daily range" is not absolutely required for conditions that result in intermittent fever is seen in the fact that this disease prevails in a great variety of climates and at all seasons of the year. W. J. H.

CURRENT NOTES.

THE SIGNAL SERVICE STATION AT CHICAGO is soon to be removed to the Auditorium building. Its rooms are at the top of the tower and its instruments will be 240 feet above the level of the street below. The Auditorium building is a noteworthy enterprise. It comprises in one a hotel, a theater, and a series of business offices, each part large enough to form a large building by itself. When the building is full it will contain about 10,000 people,—enough to make a very large village. The tower is large enough to give firmness sufficient for the meteorological instruments and is so high that it overtops everything in the city except a few spires and the water tower.

WEST INDIAN HURRICANES AND THE "MARCH BLIZZARD," 1888.—This is the title of a neat and attractive quarto publication by Ensign Everett Hayden, and is the abstract of a lecture by Mr. Hayden before the Seawanhaka Corinthian Yacht Club of New York. It is republished from this JOURNAL, but has so great additions to the text and so many plates that it will have to our readers the interest of a new publication. It is printed for the benefit of the club before which the lecture was given, but a small number of copies have been put on sale. The plates are twenty-three in number and cover much more ground than is indicated by the title, so much so, in fact, that they make with the text a compendium of information covering a large part of the field of marine meteorology, and it is all in a form which is attractive and easily understood.

THE OHIO METEOROLOGICAL BUREAU.—The sixth annual report (for 1888) gives us occasion to refer to this excellent meteorological service. The service publishes this annual report of 181 octavo pages and also thick monthly reports; it desires also to issue, like the Signal Service and several state services, a weekly crop report during the season, but this will require an additional appropriation. The legislature appropriated $2,000 for the service and it expended $2,357, drawing

for the surplus of expense on a balance on hand at the beginning of the year. There are forty-two ordinary and eleven rain-gauge stations which report to this service. This volume contains the monthly means for all stations and these are also given graphically. The observer at Wauseon, Mr. Thos. Mikesell, also gives a long series of phenological observations.

THE OREGON METEOROLOGICAL SERVICE was established at the last meeting of the legislature and two thousand dollars was appropriated for its support. Mr. H. E. Hayes, Master of the State Grange has been appointed director and Sergeant B. S. Payne of the Signal Service, assistant director. The first and second monthly reports (for April and May, 1889) lie before us. They are in quarto form, of 24 and 32 pages respectively, and, while giving the usual data for the month, they contain other reading matter in popular form. For instance, the report for May gives an account of the severe local storm of May 13th, in which the steamer *Alaskan* was wrecked off the Oregon coast, and an account of the cloud-burst in eastern Oregon on May 29th, both unusual phenomena for this part of the country. The Oregon weather service has a very interesting field for its operations.

CALIFORNIA METEOROLOGY.—Sergeant Barwick's Annual Report for 1888 contains even more than the preceding reviews which have been noticed in our columns; it contains so much that we cannot attempt to even summarize it, but must refer our readers to the author, who will doubtless send it to any one who wishes it. The report is of 188 octavo pages and is published at Sacramento. It is a report by the author to the State Agricultural Society. Sergeant Barwick is the Signal Service observer at Sacramento, and is also Meteorologist to the State Board of Agriculture.

Of especial interest in the report is the account of the unusual cold weather at Sacramento, on January 14th, 1888. The thermometer fell to 19°—with a fresh north wind,—and thin ice formed on standing water. On the same morning the tempera-

ture fell, at some points in the San Joaquin valley to 12° and at Portland, Oregon, it reached —2°, the lowest ever recorded there; the Signal Service minimum at that place had been +3°. Such cold weather had not been known before at Sacramento since 1854. On the night of January 6th, 1854, ice formed an inch and one-quarter thick and there is a record of 18° for the thermometer. Two or three inches of snow fell at this time.

THUNDERSTORMS AND HAIL IN SOUTH GERMANY.—In the Bavarian Meteorological Year-book for 1888, Dr. C. Long discusses, with reference to the velocity of progression of thunderstorms, the observations in South Germany for the ten years 1879 to 1888. The total number of thunderstorms discussed is nearly 4,000, and the deductions rest therefore on a broad basis of observation. The average progressive velocity was 38.4 km. (23.9 miles) per hour. The average velocity was somewhat greater in the first five years than in the second. The minimum velocity was in 1879 and in 1888, about the times of the sunspot minima, and the maximum velocity was in 1884-5, following a sunspot maximum. As to the relation of the velocity to the seasons;—thunderstorms travel with especial rapidity in winter, most slowly in April and May. The decrease from the winter maximum to the spring minimum is very rapid; the increase from the latter to the former is slower and has moreover a secondary minimum in September.

In South Germany thunderstorms usually come from W. or W.S.W., and their velocity of advance from these directions is greater than from any other. The storms decrease in velocity from the Main to the Alps, to increase again, apparently, on the other side of the Alps in Italy.

The daily change of velocity shows a maximum at about midnight, a minimum at about noon. This periodic change shows clearly in the averages, but individual storms show many irregularities.

In general the progressive motion of thunderstorms shows close relations with the paths of cyclones, and especially, the thunderstorm travels faster, the closer it is to the southern edge

of a cyclone and its velocity varies with the intensity of the cyclonic activity.

Dr. Franz Horn, in the same publication, gives a study of thunderstorms and hail in Bavaria for the years 1880 to 1888. He finds the curves of frequency for the two are alike, and also that hail has not been reported without the occurrence of electric phenomena sufficiently notable to be reported. Winter and summer thunderstorms differ in electric and other phenomena, and the former are much more likely to be accompanied by hail. Hail is more likely to accompany forenoon than afternoon thunderstorms.

Death of Professor Loomis.—It is with great regret that we record the death of Professor Elias Loomis. He died August 15th at New Haven, in the 78th year of his age. We clip the following facts concerning him from the daily press:

Professor Loomis was born in Wilmington, Conn., August 7, 1811, and though his father was not a wealthy man he was given a good education. He graduated from Yale with credit in 1830, and from 1833 to 1836 was a tutor in the university. Previous to this he was stationed at West Point, in company with Alexander C. Twining, where he made observations for determining the altitude of shooting stars. These were the first observations of that kind ever taken in the United States. In 1834 and 1835 he made observations of the declination of the magnetic needle. He discovered the Holley comet on its return to perihelion. In 1836 he went to Paris and attended the lectures of Profs. Drago, Biot, Dulong, and others. When he returned he was secured by the faculty of the Western Reserve college in Ohio, where he stayed about seven years. During this time he made many valuable observations in connection with the discovery of the orbits of comets.

In 1844 he went east and was made professor of natural philosophy in the University of the City of New York. He staid there sixteen years, and in that time wrote and prepared a valuable series of mathematical text books. His works on astronomy have been adopted in England. His work on analytical

geometry has been translated into the Chinese language, and some of his books have been printed in Arabic.

In 1860 he was called by the faculty of Yale to assume the chair of natural philosophy and astronomy. He was probably the greatest authority on meteorology in the United States. He was made L.L. D. by the University of the City of New York in 1854.

He gave to the world over 100 works on scientific subjects during his useful life.

Professor Loomis was a widower, his wife having died many years ago. He was alone in his last hours, so far as near relations were concerned. He has two sons, one of them in California and the other traveling in Asia. For years past his life has been one of seclusion. He seemed to care for no society but those of his books. He had not an abundance of these, but those that he had were well worn.

Shortly after commencement in early July Professor Loomis went up to Putnam to spend the long vacation. He had been at the hospital in this city two years ago for treatment for the disease of which he died. He had been at Putnam several weeks. He found that he was gradually growing weaker. He decided to visit the hospital again, and accordingly came to this city a few days ago and was carried to the hospital. From the carriage he went directly to the cot from which he never arose.

The Report of the State Board of Health of Michigan for 1888 is a volume of much scientific value. The members of the Board have shown their customary vigilance in guarding the citizens of the State from outbreaks of contagious and infectious diseases by pointing out the conditions under which they arise and recommending such measures as best prevent their spread. One feature in the method of work adopted by this Board, the holding under its management of local sanitary conventions in different parts of the State, has been productive of much good, and is worthy of imitation by other state organizations. As a means of educating the public on the importance of sanitary matters in general, but especially in directing the

attention of the residents of certain districts to their peculiar needs, no plan could be more efficient. The value to a community of a public discussion of its water supply; its sources of contamination; the dangers that are likely to arise from defective drainage; the proper management of food products, etc., cannot be over estimated. In the collection of statistics with a view of showing the prevalence of the more common diseases and their relation to the meteorological conditions at the time of their occurrence, the Michigan Board has undertaken a pioneer work of great promise. In the study of medical climatology the vital statistics that have been collected, hitherto, have not furnished the necessary data for determining the influence of the various elements of climate in causing disease. Mortality statistics are both insufficient and misleading. Deaths are frequently attributed to causes which are but terminal, while the more important predisposing influences do not appear. In the causation of many diseases climatological factors are the chief agents, while as the immediate causes of death they may oftentimes be ignored. It will be seen, therefore, that medical climatology can advance only in proportion as accurate data are collected for the purpose of determining "the time of the greatest and of the least prevalence of the more important diseases and by noting the connection of this prevalence with each of the meteorological conditions." This has been done by the able Secretary of the Michigan Board, with the best means at his command, for a decade of years, so that some inferences can safely be drawn from the accumulated facts. It is to be regretted that there is not some regulation that would require a full report of all cases of sickness occurring in all parts of the State to be reported periodically, so that those who attempt to solve such important problems would have more reliable information than it is possible to obtain from voluntary observers situated in unfavorable localities.

In this present volume the relation of climate to diseases of the air passages receives quite an exhaustive discussion, and the conclusions of the Secretary of the Board are set forth in a reprint of a paper which he read before the Ninth International

Congress at Washington. He believes, and his opinion is backed by a formidable array of figures and graphic illustrations, that the atmospheric temperature is the climatological element which determines the rise and fall of these diseases. Of this we will have something to say at another time.

CLIMATOLOGICAL WORK AT JOHNS HOPKINS HOSPITAL.—It is gratifying to all students of medical climatology to observe the careful preparation that is being made at the Johns Hopkins Hospital, Baltimore, for the record and analysis of the atmospheric conditions peculiar to that locality. It is proposed to keep a yearly record of the following conditions surrounding the hospital:

OUTSIDE AIR DAILY.

Temperature.

Three observations, 7 A. M., 2 P. M., 9 P. M.

Mamimum temperature for 24 hours.

Minimum temperature for 24 hours.

Maximum temperature of sun's rays.

Minimum temperature near the ground at night.

Barometric Pressure.

Relative Humidity.

Direction and Force of Wind.

Appearance of the Heavens.

Amount of Rainfall.

OUTSIDE AIR WEEKLY.

Amount of CO_2 present.

Bacteriological analysis.

INSIDE THE WARDS DAILY.

Temperature.

Three observations, 7 A. M., 2 P. M., 9 P. M.

Maximum temperature.

Minimum temperature.

Relative Humidity of Air.

Amount of Ventilation Going on. (Anemometric observations at inlets and outlets.)

Amount of CO_2 present in the air. (This to be determined

daily for a time until the proper rate of ventilation is established for varying circumstances).

Bacteriological Analysis. (This to be determined daily for a time until best results with different methods of cleanliness are obtained).

Lighting of Wards.

HOSPITAL MONTHLY.

It is proposed to make at regular intervals, the following analysis of the water and ice supplied to the Hospital; also a regular inspection of the filters. Analysis as follows:

WATER AND ICE.

Physical.

Transparency.

Color.

Odor.

Temperature (of water).

Chemical, Quantitative.

Residue after evaporation.

Chlorine.

Nitric acid ($N_2 O_5$)

Organic matter (expressed in amount of oxygen necessary to oxydize.

Chemical, Quantitative.

Ammonia.

Nitrous acid ($N_2 O_3$).

Free CO_2.

Hardness (quantitative if appreciable).

Biological.

Number of bacteria per cubic centimetre.

Nature of these bacteria.

Microscopic characteristics of sediment.

These observations are to be entered upon at once, at the suggestion and under the direction of Surgeon John S. Billings, who has had so much to do in perfecting the plans for this model hospital, while Dr. A. C. Abbot will have immediate charge of the observations. Such data, taken in connection with carefully recorded statistics of disease, cannot fail to increase

the accuracy of inductions as to relations of the various meteorological factors to the maintainance of health. W. J. H.

DOUBTFUL DANGERS TO NAVIGATION.—Several reports that have been received during the past month serve to illustrate the source of many of the "vigias" and other doubtful dangers to navigation that encumber the charts so long before their existence can be disproved. Capt. Gundersen, Nor. bkt. "Otto," sighted an immense dead whale July 14, lat. 43° 17′ N., long. 57° 32′ W.; at a distance it had the appearance of a rock, and a number of sea birds were about it. The German steamship "National," Capt. Heeckt, on a scientific exploring expedition from Kiel, passed a dead whale July 22, lat. 60° 11′ N., long. 23° 30′ W., with a great many sea gulls around it; a boat was lowered and the whale's head cut off and taken aboard. Capt. Evans, British steamship "Mineola," sighted an enormous dead whale August 2, lat. 57° 10′ N., long. 22° 00′ W.; its length was not less than 100 feet, and it was floating high in the water (about six feet, showing above the surface). It will readily be seen how easily such an obstruction might be mistaken for a shoal, and, if reported in a region where the depths are not too well known to admit of the possibility of such a thing, it might add one more doubtful danger to the many that have been reported.—*Pilot Chart for September.*

THE PREDICTION OF FROSTS.—The damages occasionally done in spring and autumn by unreasonable frosts make it very desirable that some means be found of predicting when a frost will occur on the following night. For some years meteorologists have pointed out a method of doing this. The method depends on the large amount of heat released when water condenses and dew is formed. The amount of heat is so great that in undisturbed weather the night temperature is not likely to fall below the dewpoint. As the dewpoint in such weather is pretty constant, that determined late in the afternoon or early in the evening is likely to give the lowest point to which the temperature will fall during the night. If this is above the freezing point, no frost need be expected; if below, a frost is probable.

The above statements are meteorologically correct, as has been repeatedly shown—quite recently by Dr. C. Lang in the Bavarian Meteorological Yearbook for 1888. But there is a difference between the question of exactness in meteorological averages and availability for practical use by those interested in the protection of plants from frost. Dr. E. Wollny, of Munich, has viewed the matter from the standpoint of practical availability, and his opinion is adverse. He points out that what the gardener, fruit and tobacco growers want, is something that can be always relied on, while the prediction of frosts by the evening dewpoint, on the average correct, cannot with absolute certainty be relied on in the individual cases. Morever, the dewpoint is usually determined at a few feet elevation, while the frost depends on the temperature of the air which is in contact with the plant. The temperature at the instrument and at the plant may differ some degrees and they are more likely to differ on a clear, calm night, when frosts are most probable, than in other weather.

We think that the judgment of any one who has tried these forecasts practically, will agree with that of Dr. Wollny, and to what he says may be added that the accurate determination of the dewpoint requires an excellence of instruments, an accuracy of observation and a skill in using tables which one would find very few, of those interested practically, willing to acquire and learn. Moreover, in the Western States at least, there are occasional conditions when the evening dewpoint does not remain even approximately constant during the night. We refer to the clearing weather which is apt to follow spring or autumn cyclones, when the drier air of the northwest follows the cyclone and lowers the dewpoint. In such cases the dewpoint at 4 in the morning may be several degrees lower than that at 9 the evening before.

Climates and Weather of India.—H. F. Blanford, lately meteorological reporter to the Indian Government, in charge of the great metereological service there established, and now living at Folkestone, England, has prepared an excellent volume

on the "Climates and Weather of India" (Macmillan, 1889), in which a large amount of well digested and trustworthy information may be found. It has the same clear style and direct statement that characterize Mr. Blanford's previous writings, and forms a model that we trust may find many followings in countries where meteorological services are established. Australia, New Zealand, Japan, the Argentine Republic, to say nothing of European countries, are all accumulating data that can in a few years be reduced to such form as this, and so become accessible to a large number of readers and students. The arrangement of Mr. Blanford's book is particularly to be commended. Ninety pages at the beginning discuss atmospheric phenomena in systematic order—temperature, pressure, winds, humidity, rain and storms—as occurring in India. Then follow one hundred pages on the various climatic districts—the hills, plains and plateaus—of the great peninsula. Finally there is an account of weather and weather reports, storms of the Indian seas, and something on the economic aspects of rainfall. Forty pages are given to climatic tables at the end of the volume.

Under the heading of weather it is interesting to find that even semi-tropical India has its shifts of wind and its rainy spells determined by cyclonic storms, in all respects similar to those which dominate the weather of temperate regions. This is fully demonstrated by the daily weather maps, based on about a hundred telegraphic reports. Even "the bursting of the monsoon" is caused by the advent of a cyclonic storm from the Bay of Bengal. Curiously enough, the summer cyclonic storms move westward over the northern plains, while the winter storms move eastward over the same region. The latter are sometimes followed by a cold northwest wind, the homologue of our cold wave. This is an interesting additional element in the strongly marked contrasts between the alternate equatorial and temperate conditions in the summers and winters of northern India.

The January and July pressure and wind charts, based on recently published data, are the best of the kind that have appeared. They were published in less complete form and without the southern end of India some years ago: now they

extend to the equator, and show the average velocity of the wind as well as its direction and the isobars. The weak gradients and light winds of the winter monsoon on land are very noticeable. The lightness of the wind is probably due in part also to the anticyclonic conditions then prevalent over much of the land, by which the diurnal convectional interchange of surface and upper currents is checked, and thus the velocity of the surface winds is almost allowed to die out. This variation is hardly apparent at sea.

Mr. Blanford is very definite in his statement as to the essentially inward spiral movement of the stormy wind in cyclones in the Bay of Bengal. He recognizes that in higher latitudes the wind near the center of a storm may blow nearly in circles; but for low latitudes, where the deflective force that turns the wind from the gradient is small, he quotes abundant experience to show that the wind blows in tolerably sharp spirals, just as we are led to expect would be the case by meteorological theory, now so well developed. The angle between the wind and the storm radius in the Bay of Bengal is given as only about five points of the compass, instead of eight as first stated years ago on less complete observations.

We heartily wish Mr. Blanford many readers—and as heartily we wish his readers many more of his books. W. M. D.

PROFESSOR FERREL'S NEW BOOK ON WINDS.*—This book will probably be a surprise to most meteorologists, for few persons have been aware that the author has been devoting considerable time during the past two years to the preparation of a popular treatise on that branch of meteorology which he has done more than any one else towards establishing on a scientific basis. We refer to the theory of the motions of the atmosphere.

Professor Ferrel's writings have been usually characterized by such brevity of expression and such a free use of the higher mathematics that comparatively few persons were able to follow his reasoning, and as his papers have always, heretofore, appeared in scientific journals of the higher class, or else in Gov-

* A Popular Treatise on the Winds—by William Ferrel, M. A., Ph. D. New York: John Wiley & Sons, 1889. Price, $4.00.

ernment publications, his views have only reached a limited number of readers. The present volume should be read by every student of meteorology, because the author, in his attempt at making the work popular, has explained at length and with great clearness, many points which in his other writings have not been given sufficiently in detail to make them fully understood without spending considerable time in thinking over the matter; and also, the views set forth in the work may be considered as the statement of the author's present ideas on the topics treated. The volume should be read by all general readers desiring information as to the motions of the atmosphere, their causes and effects, because they will find in it the opinions of the foremost authority on this subject in America, if not in the world. There are only a few pages requiring an elementary knowledge of trigonometry to understand the matter contained in them, and most of the book can be comprehended by those who have a little acquaintance with the elements of physics; and yet at the same time, there are many suggestions which will cause reflection on the part of those readers who wish to get more than an elementary idea of the subject. While the book is too bulky to be used as a text book for our high schools, yet every teacher of meteorology and physical geography would be greatly aided by reading it, and in fact it is the only available (purchasable) book that the reviewer knows of, published in this country that does give a clear idea of the principles underlying the greater and smaller atmospheric movements. The work is not a mere compilation, and the most important portions are those giving the philosophical deductions of the writer himself; but throughout the whole treatise many results and quotations are given from the writings of other eminent scientists.

In a short preface the author gives a little sketch of the gradual growth of the subject in his own mind, and states that the present book is an elaboration of lectures delivered by him in the Signal Service at Washington in 1886.

The following headings of the various chapters show the scope of the work:

Chapter I. The Constitution and Nature of the Atmosphere.

Chapter II. The Motions of Bodies Relative to the Earth's Surface.

Chapter III. The General Circulation of the Atmosphere.

Chapter IV. Climatic Influences of the General Circulation.

Chapter V. Monsoons, and Land and Sea Breezes.

Chapter VI. Cyclones.

Chapter VII. Tornadoes.

Chapter VIII. Thunderstorms.

In Chapter I, the portions treating of the dynamical heating and cooling of the air, and the stable and unstable equilibrium, are to be particularly noticed. The whole of Chapter II consists of an elementary and plain explanation of a much discussed question, and one which must be comprehended before a clear idea of the cause of the greater atmospheric motions can be understood. Special attention is called to Professor Ferrel's illustrations of the nature of the "deviatory force caused by the earth's rotation." In Chapter V particular attention is called to the author's remarks on the wind circulation along the eastern slope of the Rocky Mountains and the adjoining plains. Chapters II, III, VI and VII are particularly rich in information which Professor Ferrel has himself added to meteorological literature.

The whole book of over 500 pages is beautifully printed and neatly bound. The last 33 pages are given up to an appendix of useful tables and a list of various writings referred to by the author, and a very full subject and person index. The carefully drawn illustrations are of great assistance to the reader.

In closing, we cannot but express our thanks to Professor Ferrel for the pains and time he has taken to explain in so simple a manner the results of his own fruitful labors, as well as to bring together into a volume the information he gives concerning the results of investigations by other meteorologists.

THE AGRICULTURAL REPORT for 1888 of the general government contains one paper of interest to general readers, and that is that of forest influences on rainfall, by Mr. Fernow. If the

report were not so easily accessible to all our readers, we would be tempted to reproduce these sixteen pages in this Journal. The pages can be profitably consulted by those who wish to know the present status of this question. Besides this there are some minor references to meteorological matters, the best thing, perhaps, a sketch of the climate of Montana, by Mr. Anderson. The botanist, Dr. Vasey, is making a special study of the grasses of the arid region.

MOISTURE ECONOMY IN KANSAS.—(*Concluded from last month*). These experiments should be made with a view to determine:

1. The constituents and character of the soil, and how affected by heavy rains; whether it packs or not.

2. The character of the subsoil; whether it drains water slowly or quickly, and what is its capillary power; how far to permanent water, and if any gravel strata, or anything that would intercept or break the capillary connection between water supply and surface.

3. The percentage of rainfall absorbed or taken into the soil. The results of this experiment would necessarily be approximate and the number of experiments limited, but a few are very important.

4. Soil temperatures at various depths from surface to two feet underneath and under different systems of cultivation to be taken concurrently with air temperatures.

5. The value of subsoiling periodically to increase storage capacity for moisture.

6. The difference, if any, in amount of rainfall drained from prairie grass constantly used as pasture and cultivated land adjoining, and between prairie grass pastured and that used as meadow and not trodden upon except by horses in the necessary work of gathering the crop.

7. To what kinds of soil the application of salt or lime would be beneficial, and whether their value is in aiding the conservation of moisture or in increasing capillary power in compact soils, or whether their office is simply to prepare the plant-food in the soil for the use of the plant.

8. Weather service stations equipped as fully as stations of the Signal Service Bureau.

The exceptional severity of the drouth of 1887, covering as it did so many States, is hardly to be taken as a sample of what we have to contend with. Yet a reference to the crop statistics of 1887 and 1888 shows clearly the necessity of a better knowledge on the part of our farmers of the capabilities of their farms and how to modify the adverse influences in such seasons—a knowledge that the State alone can furnish by a geological survey and by experimental stations.

Mr. Hilton gives clearly and fully a current theory as to the origin and continuance of the western plains. We give it as given by him without, however, acknowledging it to be so important as Mr. Hilton thinks.

Keeping constantly in mind the law of capillary attraction, it is easier for us to understand what an important part the buffalo played in producing an arid climate suited to their life and wants. The constant tramping of their feet year after year manufactured a clay roof over the soil of the greater portion of the plains. It was almost water-proof. The rainfall, probably as great then as now, was rapidly carried into the streams and out of the country to the sea. What little found its way into the soil was soon evaporated because of the capillary connection with the surface afforded by the trampled soil. Only the buffalo grass, with its long, slender roots penetrating deep into the earth, and capable of maintaining its existence on a limited supply of moisture, could survive in such a hard-packed soil. This buffalo-trodden, sun-baked soil, aided by the bleached color of the buffalo-grass, reflected the sun's heat back into the atmosphere, producing an arid climate even in seasons when the rainfall, if utilized, would have been sufficient for crop production. The pioneer settlers, following close upon the retreating buffalo, or large cattle herd, had to dig their cellars with a pick. Fifteen years later a cellar could be dug out of the unbroken prairie on similar ground with a spade. The effect of the winter frost is to loosen the surface soil. With no buffalo or cattle at hand to trample it firm again and stop the threatened leaks, the

spring rains worked into the soil a little, softening the surface. Each succeeding winter's frost and summer's rains, when left to work out this problem in their own way, undisturbed by wild or domestic animals—for the pioneer settlers had but little live stock—changed the nature of the prairie sod by making it more mellow and receptive, taking into the soil more of the rainfall than was possible when the prairies were under the régime of the buffalo.

A ranker growth of grass followed the mellowing of the surface and increase of moisture in the soil. The fire-guards of the settlers; the prairie-wagon trails and the patches of breaking here and there, all combined to protect the grass against prairie fires, and promote the preservation of the grasses. These in turn shaded the ground more from the sun, and retarded the drainage of the water from the surface, by holding it in check. Thus the ranker grass on unpastured and unbroken land aids in storing the rainfall, and in preserving it when stored, so that after ten to fifteen years cellars can be dug with spade, where formerly the pick was used. If the condition of the soil could be so much modified by simply "resting" the land from wild and domestic animals, how much more benefit must follow the breaking-up of the prairie sod, which after a few years' cultivation, opened the pores in the earth's skin and induced a more natural, healthy action of the system.

The blue-stem grass covers more than double the area of Kansas that it did thirty years ago. It has always followed in the wake of settlement, and rarely preceded it. It could not find a foothold in the hard, dried-out soil of the buffalo-grass. As the ground gradually softened and increased its water-absorbing and saving qualities, the blue-stem increased. We find it in advance of settlement only in the sand-hills or sandy river bottoms that, owing to small percentage of clay, do not pack like the level prairie lands. Here the rainfall was absorbed rapidly, and the substrata seem also to have wonderful capillary power in raising moisture from below. The blue-stem selects the most moist spot on the prairie for a beginning—first a few spears, next season a little larger; many nuclei are started, and

these grow and spread, smothering the short buffalo by its ranker growth, till the whole surface is covered.

It is noticeable that where the blue-stem has taken possession of one-half of the ground, and is fenced off for pasture and stocked with cattle, that the buffalo grass more than holds its own against the encroachments of its stronger neighbor; but if a similar tract is kept as meadow, and free from stock, that the work of substitution goes on and the blue-stem prevails. Buffalo grass thrives and spreads on a tramped and compacted soil; blue-stem requires the loosened and moistened soil for its best development.

The arid climate of the plains comes more from the tramping of many feet than from any other single cause. Entirely remove the herds and keep out the prairie fires, and the climate of the plains will be modified. I do not pretend to say that the rainfall will be materially increased, or that it will be sufficient for all the agricultural products of that latitude, but the rainfall utilized will be largely increased, the heat radiated from the surface will be less, the average mid-day temperature will not be so oppressive.

Mr. Martin Allen pursues something the same train of suggestion as Mr. Hilton, but with an additional suggestion which is of interest.

In my first knowledge of Central Kansas it had scarcely a furrow plowed in its surface, and the one rule most arbitrarily enforced was the annual burning off of the grass. Sometimes this was begun as early as July or August. This grass was very short, with none of the tall sorts, or any weeds. The earth itself was very hard and compact, much like a field used to corral a large herd of stock in a wet time. It turned water almost equal to a shingle roof. These were years of extreme floods, and practically without the "dews of heaven." Since, however, we have a few plowed fields as reservoirs to hold water, and have put an end to the wholesale burning of the grass; the vacant land is much heavier coated, and with a large increase in the tall sorts. Weeds also abound wherever they can get a foothold. These all tend to prevent the old-time flow of water into the streams, and

out of the country, as well as to prevent rapid evaporation. They often gather snow drifts on level land (when before it blew away); this melts and soaks into the ground.

The result of all these influences (which are close ly allied to if not a part of, the mills of the gods), were without any per-, ceptible increase in the annual rainfall. Places that were bare only a few years ago are now well covered with herbage; the atmosphere is more moist, trees are now succeeding, that could not a few years ago be coaxed from one year's end to another. Cellars can now be dug with a spade, or plow and scraper, when a dozen years ago the pick would have been the only effectual tool, and the genial dews are no longer strangers to us.

Among the elements that may here be mentioned as valuable aids in the retention and preservation of water are, plowing the soil, or breaking the crust, so that water may the more readily penetrate it, which may be followed by subsoiling or trench plowing, so that a surplus of water at any time may the more readily sink down deeply, where it will be held in reserve for the time of need, and not to be forced from necessity to pass rapidly over a hard and often sloping surface toward the sea.

Saving the natural growth of grass from being burned has from actual observation a most wonderful effect, not only in preventing the free passage of water following a rainfall out into the neighboring streams, but to prevent evaporation as well. To understand these matters in their full force, the observer must, as I have done, both examine adjacent burned and unburned lands at the time of and closely following a rapid rainfall. And again, put a breaking-plow into both burned and unburned lands just at a time when it is getting too dry to break land with ease.

Probably the initiatory steps in preservation of water upon the plains was taken by the buffalo bulls—digging up the dry dust with their hoofs and horns, while challenging their rivals to combat. These "wallows," as they are called, have been deepened from time to time by the wind blowing the dry dust out of them; and even now, it is believed that if they could only be kept continually full of water, this alone would have a vast

ameliorating influence upon the moisture of our atmosphere, it having been repeatedly observed that whenever these buffalo-wallows are full of water, the ground is not only in good condition, but the atmosphere also, for the favorable growth of crops generally.

Therefore, let us improve upon what the buffalo has begun for us. Let us, in working or making our public and private roads, do just the opposite of what the people are compelled to do where the surface of the whole country is more level and therefore moisture more abundant. Indiana and Illinois annually spend large sums of money to get rid of their surplus moisture along their highways; in other words, to cure their mud-holes by various devices of ditching, draining, filling and putting in bridges, culverts, etc. All these are among what are known as public improvements over vast areas of the Eastern and Middle States, but deemed quite unnecessary in Kansas, especially in the central and western parts, that are supposed to be suffering for the want of moisture.

Now, let us in making and working all our public and private roads, whether we need them or not, make dams wherever such roads cross over slight depressions. These will be found very numerous — say from three to five for each mile. But for the sake of argument let us suppose there are only two to each mile of road and a road on every section line: this calculation would give to the western two-thirds of our State the enormous number of 212,800 such dams. And suppose these on an average to each cover one-fourth of an acre and to be of an average depth of only one foot: you can each of you figure out for yourselves the vast amount of water that would be retained from passing at once away to the sea. You can also imagine for yourselves the effect of the storing up of such a surplus. Let it soak into the ground: is it not simply preserved and stored up for the time of need? Or should it be evaporated and go into the atmosphere? Let us remember it takes water to make rain, and don't let us lose hope in getting back at least a portion of it in this form.

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